Edited by Bill Travis

High-side current monitor operates at high voltage

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The simplest technique for measuring current in an actuator or a motor is to monitor the ground current with a resistive element between the load and the ground. Because the device and its associated electronics share a ground potential, you need to amplify only the ground-current signal. This approach, however, does not detect device short circuits to ground, which can overload the high-side drive circuitry. To avoid such potential fault conditions, you should use a high-side current monitor to detect short circuits and similar faults that can occur following the current monitor. High-side current monitoring has advantages, but it finds limited use because of the dearth of devices able to handle the high voltage levels—24V to many hundreds of volts—prevalent in the industry. Off-the-shelf devices can operate to 32 and 76V, but even 76V is insufficient for many applications. **Figure 1** shows a simple way to adapt a standard 32V device for use at any voltage level, subject to limitations of the external components. (The components in **Figure 1** can accommodate 130V.)

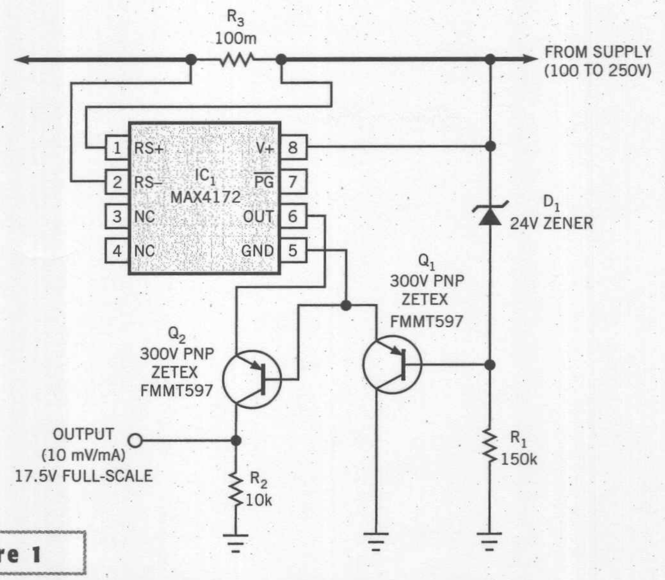

Figure 1

This circuit enables a 36V current-monitoring IC to operate at common-mode voltages as high as 130V.

The accuracy of the circuit is better than 1% for load currents greater than 30 mA. IC_1's current-output stage allows easy implementation of the current mirror needed for level-shifting the output signal to ground. Thus, you can easily monitor the ground-referenced signal by using an A/D converter or a comparator. The circuit monitors load current in the presence of a 130V-dc common-mode level. You must ensure that you do not violate IC_1's absolute maximum rating—36V with respect to the ground pin—for the RS+, RS−, and V+ pins. For that purpose, zener diode D_1 limits the voltages between the V+, RS+, and GND pins to 24V. Thus, the typical voltage between these pins is 24V minus the V_{BE} of Q_1, or 23.3V. The zener-diode current for this circuit is approximately 700 μA. Note that the manufacturer's suggested bias current is 500 μA, but the zener diode's di/dt slope goes *negative* below 300 μA, a condition that can introduce noise or even oscillation. The minimum specified bias—300 to 500 μA—sets the maximum value of R_1, and the maximum allowed power dissipation for R_1 and D_1 combined sets the minimum value for R_1. Thus, for supply rails of 100 to 250V, a reasonable R_1 value is 150 to 225 kΩ—1 150 kΩ in this case.

Q_1 and R_1 form a shunt regulator. The design uses Q_1 because of its maximum V_{CE} rating of −300V, high gain of 100V/V at 1 mA, and its ability to handle 500 mW of power. Output current is proportional to the voltage difference, V_{SENSE}, between RS+ and RS−: $I_{OUT}=g_m \times V_{SENSE}$, where $V_{SENSE}=R_{SENSE} \times I_{LOAD}$. Transconductance for IC_1 is 10 mA/V. If the maximum monitored load current, I_{LOAD}, is 4A, and R_{SENSE} is10 mΩ, then the maximum I_{OUT} is 10 mA/V×10 mΩ×4A=400 μA. Thus, I_{OUT} is proportional to I_{LOAD}, and the maximum expected output is 400 μA. For applications of wide dynamic range in which V_{SENSE} can approach the absolute maximum rating of the differential pair, 700 mV, you should protect the sense pins by adding series resistors between R_{SENSE} and RS+ and between R_{SENSE} and RS−. You should select the resistor values to limit input currents to within 10 mA when the RS+ to RS− difference is 700 mV.

I_{OUT} is now proportional to I_{LOAD}, but, for easy monitoring, you must level-shift it to ground by using the Q_1-Q_2

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current mirror. Q_2's high gain forces the collector current to closely approximate the emitter current which, when you apply it to R_2, produces a measurable voltage at V_{OUT}. As with Q_1, Q_2 needs a maximum V_{CE} rating of −240V. The device in **Figure 1** is rated at −300V. V_{OUT} now equals $I_{OUT} \times R_2$. (The actual output current at Q_2's collector is slightly less, because of Q_2's base current.) At I_{LOAD}=4A, V_{OUT}=400 μA×10 kΩ=4V. You can accommodate designs with lower or higher operating voltages by properly selecting Q_1, Q_2, and the base resistor, R_1.□

Digital potentiometers enable programmable biquadratic filter

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Of the many types of analog filters available to designers, few allow easy adjustments of the filter parameters. The biquadratic, or biquad, filter is an exception, however. You can change that filter's corner frequency (ω_0), Q, and gain (H) by adjusting the values of three resistors. For that purpose, the lowpass biquad circuit of **Figure 1** includes three digital potentiometers configured as variable resistors in the feedback loops. Altering the settings of these potentiometers changes the filter characteristics. The circuit produces corner frequencies of 5.5 to 55 kHz; Q values of 0.055 to 5.5, depending on the selected corner frequency; and gain of 1 to 100, also depending on the selected corner frequency. To tune the biquad filter, you set a corner fre-

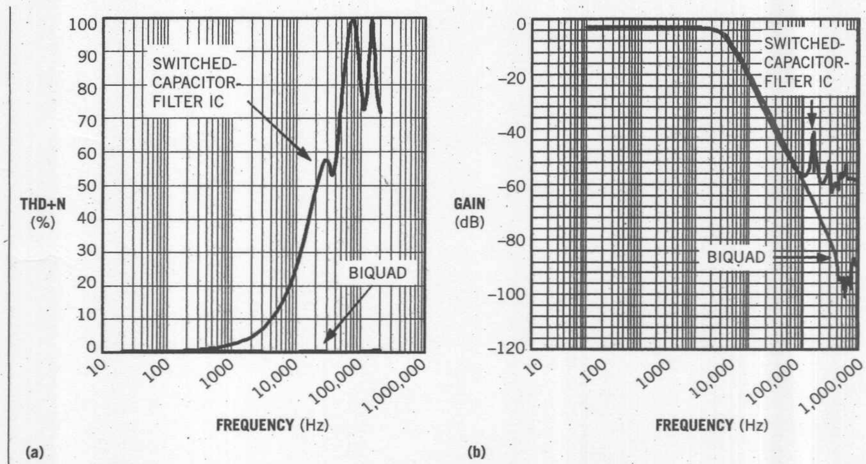
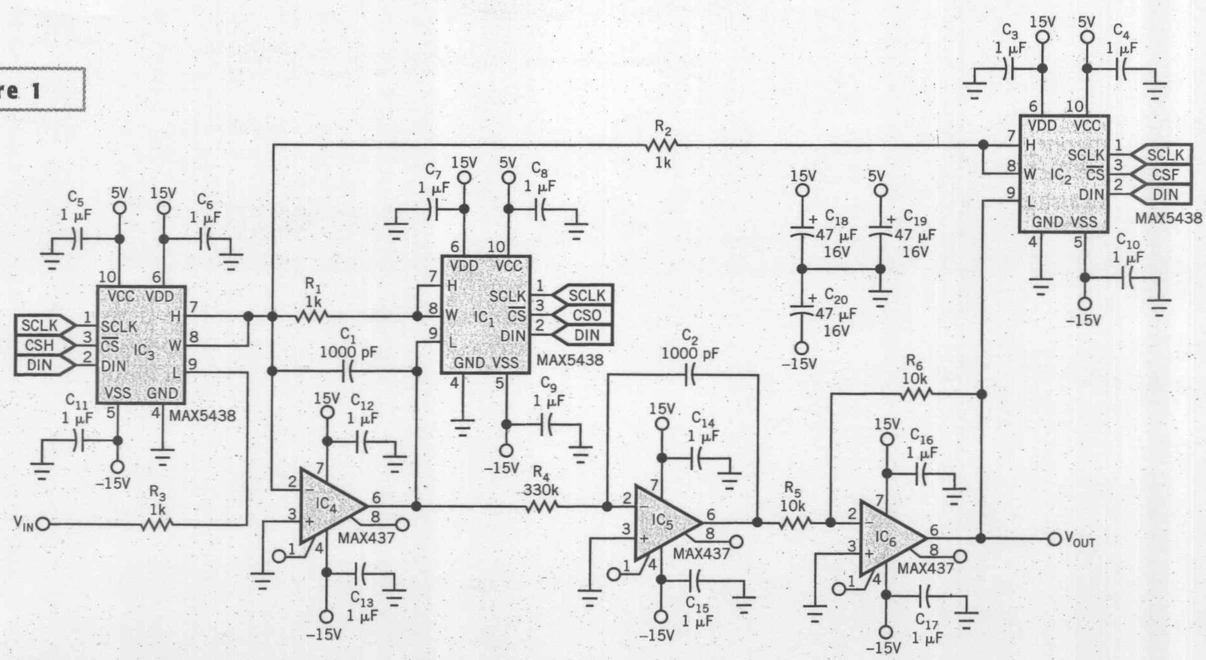


Figure 2 Noise (a) and low bandwidth (b) plague switched-capacitor filters. The biquad filter of Figure 1 maintains less than 1% THD+N over the range 20 Hz to 200 kHz.

Figure 1



Digital potentiometers adjust the corner frequency, Q, and gain for this biquad analog filter.